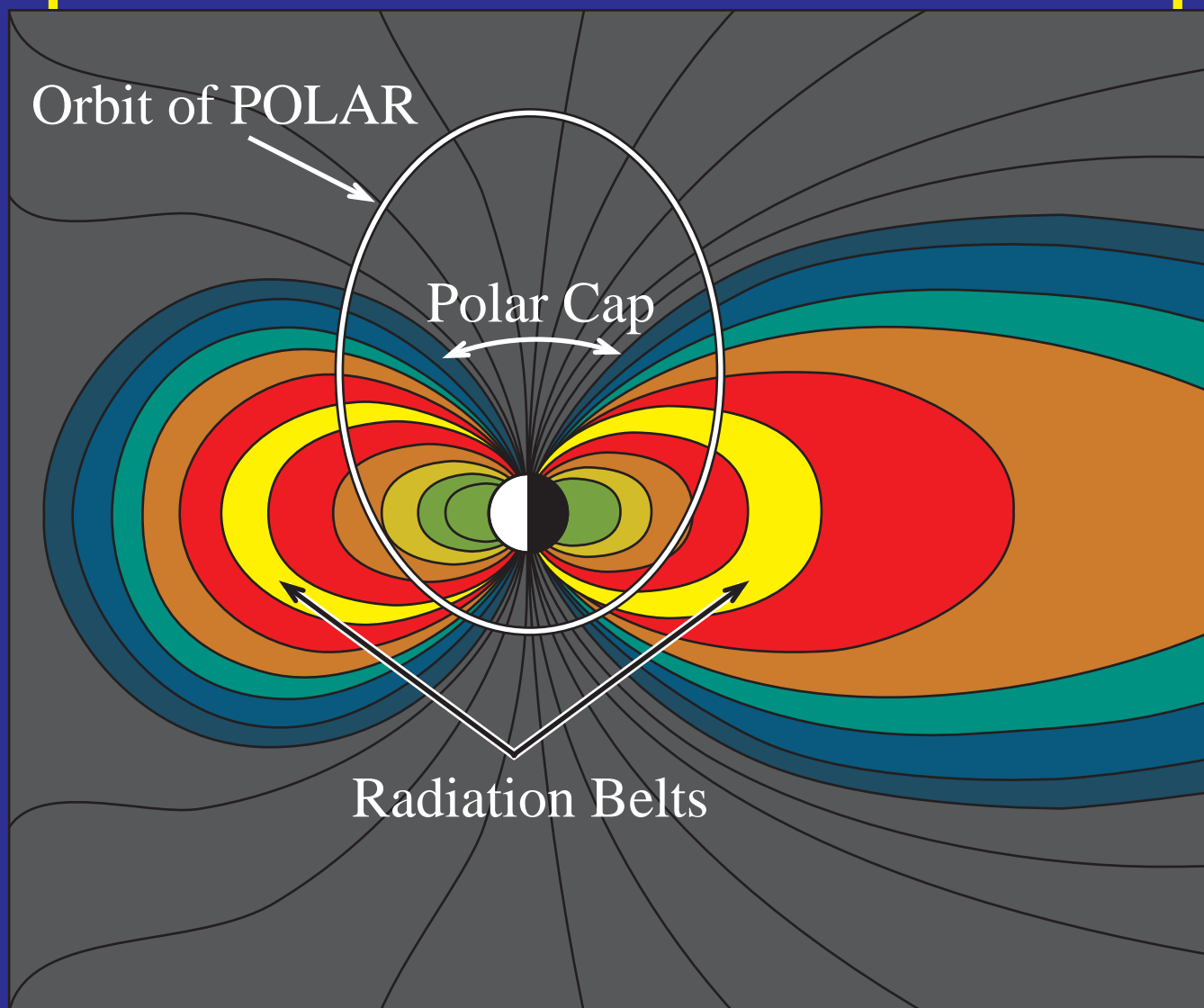


ISTP Accomplishments In Magnetospheric Science



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ISTP Science Workshop – April 6-9, 1998





Fundamental Developments

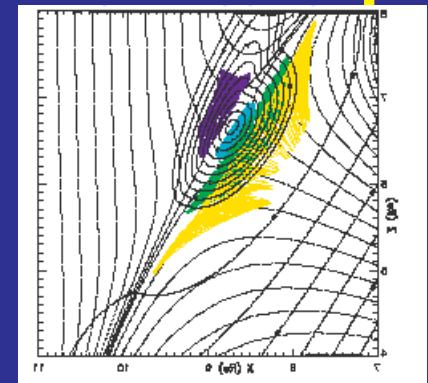
- There is no debate that CMEs are highly geo-effective solar wind disturbances.
- We now know that relativistic electrons are accelerated within the magnetosphere and on a wide variety of time scales.
- The inner magnetosphere is important for substorms but is also not the whole picture. Only the coupled inner magnetosphere and tail systems can produce observed substorm signatures.
- Storms are more than simply a collection of substorms.
- Pre-History is important: the pre-existing conditions in the plasmasheet and possibly even the plasmasphere affect ring current development.
- There is a new emphasis on polar cap processes, high-latitude reconnection, etc.
- Many processes that were known or suspected are now being studied in a quantitative manner.
- Global MHD models have now become practical data analysis tools.
- The time-scale for event studies is near-real time. Compare Nov. 1993 & Jan. 1997 storms - they're being published in the same special issues!
- Difficulty organizing this talk reflects how interconnected our studies are. You can't organize by instrument or even by satellite. How do we separate the topics of "Energy Transfer", "Particle Transport", "Magnetospheric Structure", "Storm/Substorm Dynamics", etc.





High-Latitude, Polar Cap, & Cusp Studies

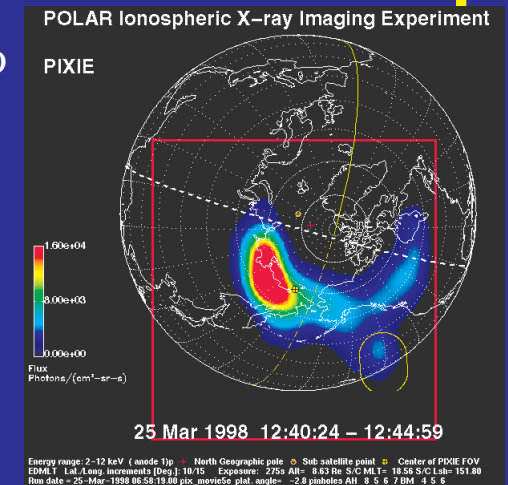
- Broadband plasma waves discovered at the polar cap boundary layer. They are similar to waves known to exist at the low latitude boundary layer.
- Identification of coherent electric field structures in the high altitude polar magnetosphere. Similar structures have been found in the auroral zone below 4000 km and in the far geomagnetic tail.
- Energetic particles observed in or near the cusp. Evidence for trapping, cusp acceleration, or other unknown processes.
- Polar Energetic Particle (PEP) events are evidence for and diagnostics of high-latitude reconnection.
- First direct observation of polar outflow of ionospheric ions down to energies of a few volts.



- Polar outflow contains more Oxygen than expected and prove that O⁺ outflow is dominated by the dayside auroral plasma fountain but are found to be highly variable
- New models of polar outflow and re-entry into the plasma sheet have been developed.
- Thermal plasma and composition studies show evidence for both quasi-steady reconnection and multiple-reconnection and flow of material across the magnetopause in both directions.

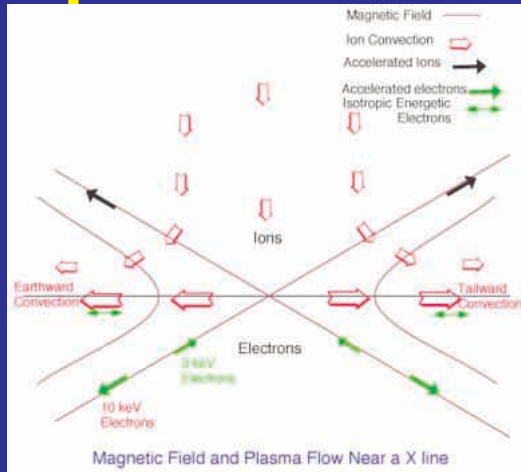
The Auroral Zone

- New understanding of theta auroras and their relationship to magnetospheric plasma boundaries.
- First auroral x-ray images from earth-orbiting satellites.
- Quantitative studies of energy input into the auroral zone
- New studies of auroral conjugacy.
- Observation of energization and escape of ionospheric plasma in the upward auroral FAC region.
- Confirmation of predictions of Newell et al. that photoelectrons suppress optical aurora and upward flowing ions.
- Detection of large parallel electric fields in the up-going field aligned current portion of the auroral acceleration region, comparison to in situ plasma measurements, and relationship to theory of double layers or electrostatic sheaths.
- Discovery of four fundamental and new electric field time domain structures in the auroral acceleration region:
 - large amplitude solitary waves,
 - spiky field structures, (responsible for \parallel DC fields?)
 - wave envelopes, and
 - very large amplitude nonlinear, coherent ion cyclotron waves





The Magnetotail

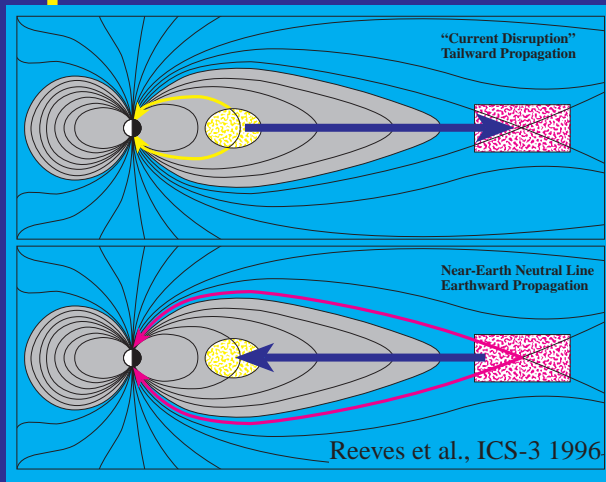


- An extensive survey of magnetotail plasma, energetic particles, magnetic fields, and plasma waves throughout the magnetotail.
- Unprecedented 3D plasma distributions.
- The most complete characterization of and new insights into neutral line formation and plasmoid structure.
- Definitive identification of the region of neutral line formation.
- Observation of flow bursts exceeding 1000 km/s and new understanding of their role in magnetospheric substorms.
- Demonstration that energetic ions of solar wind origin (He^{++}) and of ionospheric origins (O^+) are thoroughly mixed inside flux ropes or plasmoids, just like the ion composition in the tail outside these structures.
- Observation of energetic O^+ flow bursts in the magnetotail during substorms.
- Numerous detailed studies of storms, substorms, and their effects on the magnetotail.
- Discovery of the “superdense” plasma sheet and its role in storm development.



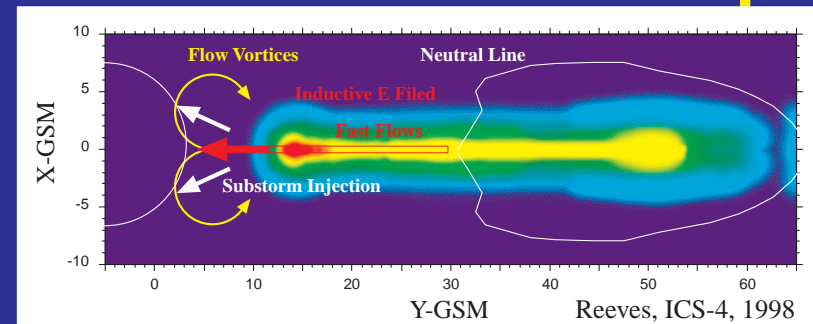


Storms and Substorms



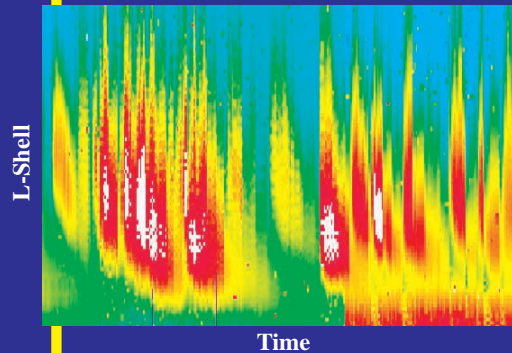
- A fundamental change in the debate over substorm onset and substorm phenomenology.
- Both near-Earth and mid-tail processes are widely acknowledged to play important roles in substorms.
- Debate has shifted away from “which comes first?” to “how are things coupled?”.
- The growing consensus is that bursty bulk flows are the mechanism that couples the two regions. This is supported by simulations and theory.

- Substorm injections have been quantitatively modelled and show remarkable agreement with geosynchronous observations.
- Storms are recognized as being a combination of substorm effects plus global convection rather than just a collection of substorms.
- The condition of the plasmasheet has been found to be a controlling factor in the development of the storm time ring current.
- Relativistic electron enhancements have been found to be a fundamental response of the magnetosphere during solar-minimum storms.



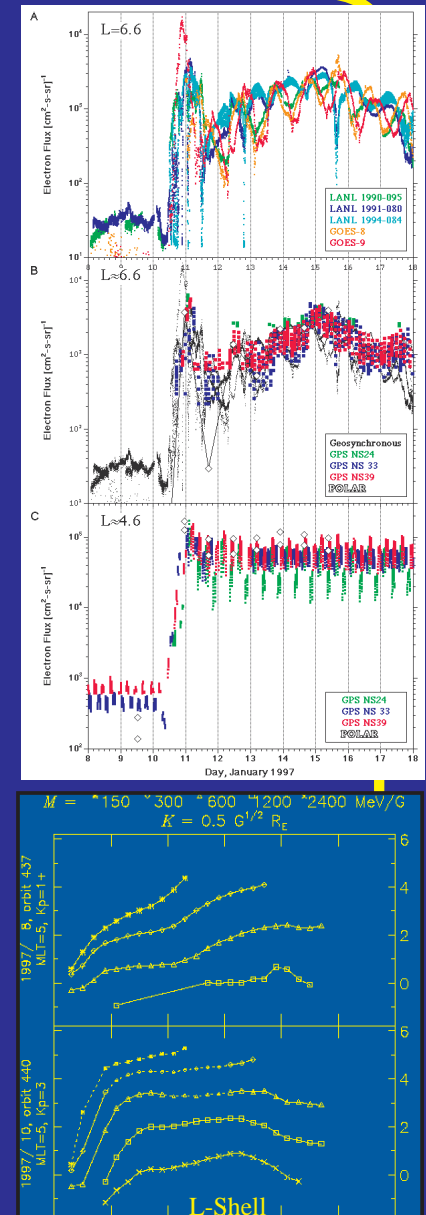
The Radiation Belts

Polar HIST >2 MeV Electrons



- Relativistic electron events have become a hot topic again.
- “Dropouts” during main phase of storms was shown to be primarily an adiabatic effect.
- Solar wind found to be an insufficient source for trapped relativistic electrons.

- January 1997 event analyzed in great detail by more than 15 satellites, and numerous ground stations revealing new and unexpected features of relativistic electron events.
- Acceleration in events can be rapid - a few minutes for energies below 1 MeV and a few hours for energies above 1 MeV.
- Wave-particle interactions now suspected of being an important acceleration mechanism.
- Localized peak in phase space density proves internal acceleration.
- Magnetospheric compression can cause large-scale quasi-adiabatic transport of particles in the radiation belts.
- Diffusion rather than acceleration found to be cause of delayed peak typically observed in the outer radiation belts.



Energetic Neutral Atom Imaging

- One of the big “surprises” of the POLAR mission.
- First ENA composition measurements were obtained by the GEOTAIL EPIC instrument.
- First ENA images of storms and of substorms.
- First ENA movies – visualizing global dynamics.



- Excellent correlation between ENA substorm observations and in situ injection data.
- Excellent correlation of ENA fluxes with both Dst index and in situ ring current measurements
- Rapid development of forward and inverse modelling techniques.
- Development of statistical tools and superposed epoch studies.

Unsmoothed Composite Image of Four Substorm Injections



Scientific Infrastructure

- Open Data Policy
 - + open software
 - + summary plots
 - + publications, etc.
 - = enhanced information exchange
- Public Outreach / Public Relations
- Ground & Non-NASA data sources.
- Multi-satellite and multi-instrument studies have

